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Effects of infrequent watering on Boran cattle

Small-scale dairy production in Africa

Small ruminant production in tropical Africa

Research with a farming systems perspective ILCA

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## Preface

This issue of the *ILCA Bulletin* includes a study on the implications of infrequent watering for cattle productivity under extensive pastoralism and ranching in Ethiopia, an article analysing some of the constraints to smallholder dairy production in Africa, a paper on small ruminant production in tropical Africa and possible improvements, and an article on farming systems research at ILCA.

The first paper examines the effects of 1-, 2- and 3-day watering on birth and weaning weights, post-weaning growth and cow performance in the Borana pastoral system in Ethiopia. The author found that although animal productivity was lower under 2- and 3-day watering, the strategy is appropriate in areas where water and labour are in short supply. In addition to saving these resources, 3-day watering enables pastures further from water to be exploited, conserves fodder reserves and lessens erosion in the vicinity of water points.

The second paper summarises the major environmental and organisational constraints to increasing dairy production in Africa. Any measures proposed to eliminate these constraints must be cost-effective, should concentrate on improving animal health, dry-season feeding, calf rearing, small-scale milk processing and marketing facilities, and should be implemented within an organisational framework providing the necessary technical services and adequately trained personnel.

The author of the third article believes that improving small ruminant production in tropical Africa by introducing, low-cost nutritional interventions offers another possibility for increasing overall food production in the continent. The proposed interventions include cut-and-carry feeding and provision of water in pens, salt licks, better utilisation of crop residues and regrowth on fallowed fields, of household wastes and otherwise unusable byproducts from small-scale food processing, and preferential feeding of supplements to pregnant and lactating animals.

ILCA's experience with farming systems research is described in the fourth article. Having given emphasis initially to detailed baseline studies on the socio-economic environment in which livestock producers operate, the Centre's scientists found that Western technology and the results of on-station research, whether in Africa or elsewhere, could not be transferred directly to African traditional systems. As a result ILCA has recently emphasised component research to generate new technology suitable for increasing the productivity of the livestock component and of the farming system as a whole.

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# The cost to productivity and the potential benefits of 2- and 3-day watering of Boran cattle\*

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\* This is a modified version of the article entitled 'The effects of drinking frequency on some aspects of the productivity of zebu cattle' which was accepted for publication in the Journal of Agricultural Science.

## Summary

A 28-MONTH TRIAL was conducted under extensive grazing conditions to examine the effects of watering Boran cattle once daily, once every 2 days and once every 3 days, with cattle watered ad libitum serving as the control. In the dry season, the weight and condition of lactating cows watered every 3 days declined more rapidly than that of cows watered daily. There were no significant differences in calving rates and birth weights among treatments although birth weights were depressed by 2.5 kg in all treatments compared with the control. Thirty steers showed no treatment differences in 27-month weights despite animals watered every 3 days having a significantly lower DM intake during the dry season. In contrast, 210-day weaning weights were significantly depressed by 9 kg under 2-day watering and by 14 kg under 3-day watering when compared with calves watered daily. The total amount of water consumed was reduced by 5–10% in all classes of stock under 2-day watering and by 25–34% under 3-day watering, compared with cattle watered daily. The results show that watering every 3 days can be carried out indefinitely with all classes of stock with only minor effects on cattle productivity under the climatic conditions in which the trial was conducted. The management implications of 2- and 3-day watering in cattle under extensive pastoralism or ranching are discussed.

## Introduction

The Borana pastoral tribe in southern Ethiopia and northern Kenya water their cattle every 3 days (Dahl, 1979). In the past, the Maasai and other pastoral tribes also adopted this practice, but have discontinued it, presumably due to increased water supplies. In other pastoral regions of Africa, alternate-day watering is resorted to in the dry season (Bailey, 1982; Maliki, 1981; King, 1983; Nicholson, 1985a).

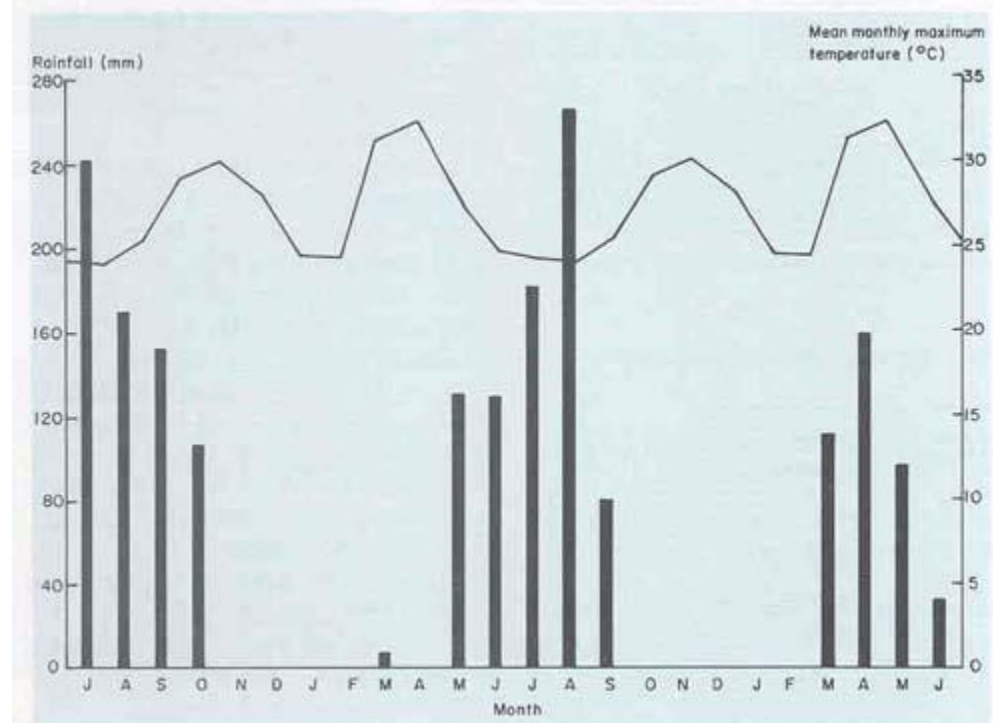
French (1956) studied the effects of 2 and 3-day watering on water and feed consumption and subsequent digestibility of hay in stall-fed *Bos indicus* oxen. However, the trial was of short duration and weight change was not monitored. Payne (1965) examined the effect of 1-, 2- and 3-day watering on 10 sets of identical zebu or zebu-crossbred twins. One of each twin was watered daily and served as the control, and the other was watered intermittently on a 1-, 2- or 3-day cycle and subjected to varying walking distances. After 2 years, the control animals had an average weight of 151 kg, compared with 131 kg for the experimental animals. Payne concluded that the influence of walking on liveweight gain was much less than that of water deprivation, but that the effects of both were small relative to those of seasonal changes in the quality and quantity of grazing.

No experiment has previously studied the effect of infrequent watering on breeding cows and their offspring. This study was conducted to determine whether watering cattle every third day constituted a constraint on productivity in the Borana system. The effects of 2- and 3-day watering needed to be quantified, since it was assumed that there is a trade-off between the expected lower animal productivity and the possible benefits of the practice. The main factors studied were the effects of 3-day watering on cow performance, and on calf and subsequent weaner growth.

## Materials and methods

The trial was carried out on the Abernossa ranch in the Ethiopian Rift Valley at an altitude of 1700 m and a latitude of 7°50' N. Average rainfall is between 500 and 700 mm, seasonal in distribution, falling mostly between July and September but with unreliable short rains in April. Rainfall was measured as the average figure from two equidistant rain gauges and was 928 and 681 mm in 1983 and 1984 respectively. The rainfall distribution and mean monthly maximum temperatures during the 28-month trial (July 1983 to September 1985) are shown in Figure 1.

**Figure 1.** Rainfall and temperature data, Abernossa ranch, 1983–85.



Seventy-five Boran cows with male calves were allocated to one of three treatments on the day of calving. One Brahman heifer and three Friesian x Boran crossbred cows were also allocated to each treatment. The treatments comprised daily watering (treatment 1), alternate-day watering (treatment 2) and 3-day watering (treatment 3). Each group was allowed unrestricted grazing in one of three paddocks of 90 ha each, in which the pasture was dominated by *Cenchrus ciliaris*, *Chloris gayana* and *Hyparrhenia hirta* in a dense acacia woodland. Feed was generally plentiful even at the end of the dry season, although quality was poor. No supplements were given to the cows. Groups were rotated monthly among the paddocks to avoid a confounding effect of paddock condition. Fifty cows from the ranch, watered *ad*

*libitum* but otherwise treated identically, served as a control group. However, as these were not under the direct control of the experiment, data on the performance of 2- and 3-day watered cattle are presented in comparison with daily watered cattle unless otherwise stated. In practice, *ad libitum* watering of cattle in pastoral regions is extremely rare in the dry season.

Health control was restricted to spraying against ticks as part of the ranch programme and infrequent vaccination against foot-and-mouth disease. Both were limited by shortages of acaricide and vaccine.

Bulls ran with the cows from late September to December so that calving was seasonal and coincided with the main rains. Suckling was unrestricted and calves had access to all their dam's milk. Calves were weaned monthly at between 210 and 240 days of age. At the end of the first year, 10 weaners in each treatment were castrated and returned to their original treatment to measure post-weaning growth. At 27 months old, these steers were put on *ad libitum* watering for 6 weeks.

All animals were routinely weighed each month before and after watering except during changeable weather during the rainy season when they were weighed twice a month, since water intake, and hence weights, varied according to the weather. At the same time, the condition of lactating and dry cows was recorded using the nine-point scoring system of Nicholson and Butterworth (1985). Heart girth was measured in all stock. Skeletal size was taken as the height from the ground to the dorsal head of the supraspinous fossa on the scapula and the length from the *tuber ischii* to the scapula over the *tuber coxae*.

Animals were given access to water at 11 a.m. for 15 minutes, the difference in body weight before and after drinking representing water consumption. Weight losses due to defaecation and urination during watering were rare, and were therefore ignored.

Dry-matter (DM) intake was estimated in six steers and nine lactating cows per treatment. In steers, intake was estimated indirectly using a combination of a natural marker (indigestible acid detergent fibre (IADF) determined in feed and faeces (van Soest, 1982) after a 96-hour *in vitro* digestion) and 10-day whole faecal collection. Grass was collected during grazing by grab sampling. Samples were bulked during any one grazing period and 10 bulked samples were dried, ground and analysed for each faecal collection period. In cows, DM intake was determined under stall-feeding, where the marker and faecal collection could be validated with direct measurement of feed intake. Tritiated water was used to measure milk intake over 10-day periods in young calves (turnover method), and the measurements were validated by weighing prior to and after suckling (Coward et al, 1982). Measurement of total milk yield is not feasible in *Bos indicus* under field conditions; hence weaning weights were assumed to be a reflection of milk consumed by the calf.

The model used for the analysis of weights included linear and quadratic orthogonal components for treatments. Least-squares means (Harvey, 1982) are given with their standard errors for the analysis of calf and steer weights.

## Results

### Calving percentage

Although the trial included three calving seasons, July 1983, July–September 1984, and July–September 1985, the first season was independent of the treatment effect; therefore only two calving seasons were considered. There were no significant differences either between years or among treatments, despite 1984 being a particularly dry year.

### Birth weights

At the start of the trial birth weights of calves averaged 26.4 kg. For all treatments, 1983 birth weights were significantly heavier ( $P < 0.001$ ) than those of 1984 or 1985 (Table 1). In the last 2 years there were no treatment, sex or year effects. Calves from *ad libitum*-watered cows were significantly heavier ( $P < 0.001$ ) than all the treatment calves in both 1984 and 1985.

**Table 1.** Calf birth weights (kg  $\pm$  S. E.), 1983–85.

Treatment	1983	1984	1985	1984/85
1	26.3 <sup>a</sup> $\pm$ 0.26	24.7 <sup>b</sup> $\pm$ 0.73	23.2 <sup>b</sup> $\pm$ 0.76	24.0 <sup>b</sup> $\pm$ 0.52
2	26.7 <sup>a</sup> $\pm$ 0.38	23.7 <sup>b</sup> $\pm$ 0.66	23.5 <sup>b</sup> $\pm$ 0.74	23.6 <sup>b</sup> $\pm$ 0.54
3	26.4 <sup>a</sup> $\pm$ 0.36	23.3 <sup>b</sup> $\pm$ 0.71	22.9 <sup>b</sup> $\pm$ 0.70	23.1 <sup>b</sup> $\pm$ 0.54
Control	26.3 <sup>a</sup> $\pm$ 0.24	26.1 <sup>a</sup> $\pm$ 0.42	25.7 <sup>a</sup> $\pm$ 0.53	25.9 <sup>a</sup> $\pm$ 0.51

Means in the same column with the same superscript are not significantly different at the 5% level.

Month of birth had a significant effect ( $P < 0.05$ ) on calf weights at birth and at 210 days of age (Table 2). Seventy-four percent of calves were born in July and August. There was no significant interaction between treatment and month. However, the 31 calves from cows in treatment 1 were born significantly later ( $P < 0.01$ ) than the 68 calves from cows in treatments 2 and 3. This amounted to a difference of between 2 and 3 weeks.

**Table 2.** Calf weights (kg  $\pm$  S.E.) at birth and at 210 days old by month of birth (1984 and 1985 combined for treatments 1, 2 and 3).

Month of birth	Birth weight (kg)	n = 99	210-day weight (kg)	n = 115
June	22.0 <sup>a</sup> $\pm$ 0.84	9	127.9 <sup>a</sup> $\pm$ 9.82	3
July	24.1 <sup>bc</sup> $\pm$ 0.38	50	143.7 <sup>ab</sup> $\pm$ 2.74	44
August	24.7 <sup>b</sup> $\pm$ 0.49	27	135.3 <sup>ac</sup> $\pm$ 2.78	41
September	25.1 <sup>bc</sup> $\pm$ 1.27	4	132.7 <sup>a</sup> $\pm$ 5.98	8
October	21.9 <sup>ac</sup> $\pm$ 1.02	9	120.2 <sup>ad</sup> $\pm$ 4.22	19
Mean	23.5 $\pm$ 0.38		136.3 $\pm$ 18.37	

Means in the same column with the same superscript are not significantly different at the 5% level.

## Weaning weights

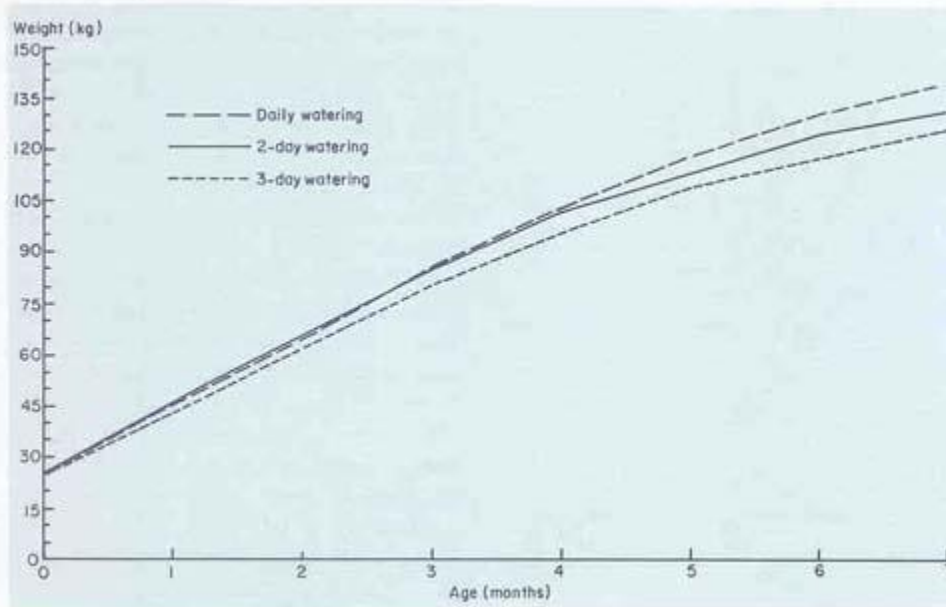
The 210-day weaning weights of calves are shown in Table 3.

**Table 3.** *Two-hundred-and-ten-day weights (kg  $\pm$  S.E.) of calves born in 1983 and 1984.*

Treatment	1983 calves (n = 98)	1984 calves (n = 101)	1983 and 1984 calves (n = 199)
1	142.1 $\pm$ 3.58	139.8 $\pm$ 5.56	139.6 $\pm$ 3.40
2	136.5 $\pm$ 3.91	133.8 $\pm$ 5.20	130 8 $\pm$ 3.35
3	132.0 $\pm$ 3.80	125.6 $\pm$ 6.39	125.5 $\pm$ 3.76
Control	147.3 $\pm$ 5.82	143.9 $\pm$ 6.81	146.2 $\pm$ 3.98

The linear effect of watering frequency on calf weight was significant ( $P < 0.05$ ) at all ages over 90 days. Sex, weight at birth and year of birth did not have significant effects but month of birth significantly affected weaning weight (Table 2). Calf growth from birth to weaning at 7 months is shown in Figure 2.

**Figure 2.** *Effect of watering regime on calf growth from birth to weaning (1983 and 1984 calves combined).*



## Mortality

Two-hundred-and-one calves were born in the trial over the three calving seasons. One 19 kg calf died of cutaneous streptothricosis at 2 weeks of age and one 25 kg calf died at 3 days old,

apparently from choking on milk. Both calves belonged to treatment 1. Overall calf mortality was therefore 1 %.

Four cows died during the study period. The causes of death were plant poisoning (1), punctured abdomen (1), possible cardiac failure (1) and septicaemia (1). None of the deaths was attributable to treatment.

## Post-weaning growth

The weights of 1983 and 1984 weaners were examined separately since the animals in the first group were not significantly different from each other at weaning or at birth. Weights of steers at various ages are shown in Table 4. No data were available on control steers as male calves are either sold or kept for breeding purposes.

**Table 4.** *Weights of 1984 male weaners (kg  $\pm$  S. E.) at 12, 15, 18 and 24 months old.*

Treatment	Age (months)			
	12	15	48	24
1	191.4 $\pm$ 15.9	218.7 $\pm$ 6.1	230.0 $\pm$ 6.8	312.8 $\pm$ 8.4
2	188.0 $\pm$ 15.1	210.2 $\pm$ 7.2	216.3 $\pm$ 8.0	308.4 $\pm$ 9.4
3	209.0 $\pm$ 15.1	215.5 $\pm$ 7.1	215.5 $\pm$ 7.9	306.1 $\pm$ 9.2

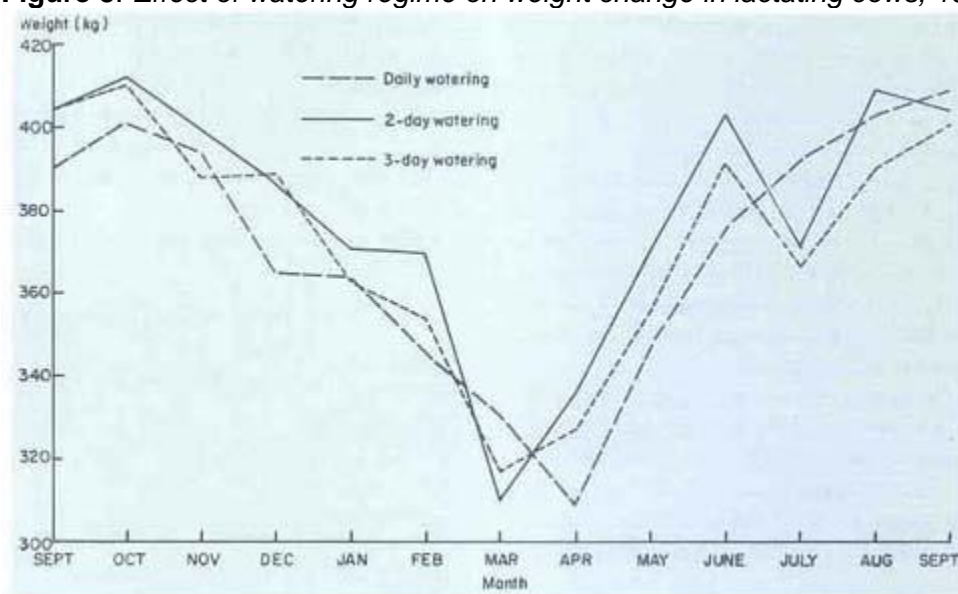
Watering frequency did not have a significant effect on the weight of steers in 1984 at any age up to 2 years old. In 1985, treatment 3 weaners were significantly lighter ( $P < 0.05$ ) at 1 year old ( $160 \pm 6.9$  kg) than those in treatment 1 ( $177 \pm 6.9$  kg) and treatment 2 ( $178 \pm 5.6$  kg). Sex differences in the 1985 weaners were not significant but at 12 months in these animals the treatment linear component was significant ( $P < 0.01$ ). Treatment did not have a significant effect on skeletal size at any age, suggesting that weight differences reflected variations in muscle, fat reserves or gut fill. After 6 weeks of *ad libitum* watering, mean weights were 357, 374 and 371 kg for treatments 1, 2 and 3 respectively. The differences were not significant.

## Seasonal change in cow weight

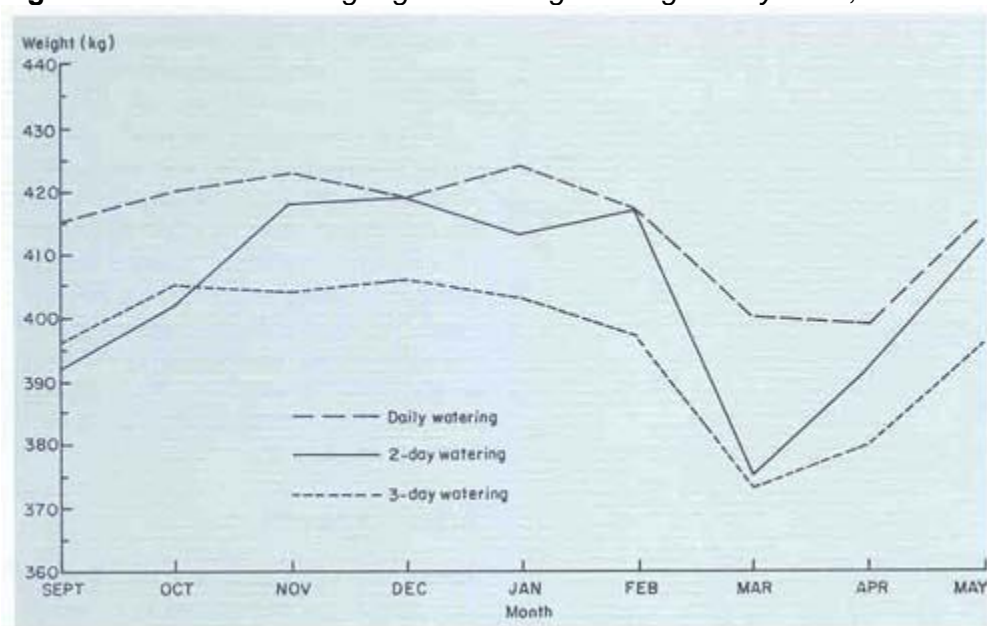
Weight loss in lactating cows during the dry season is shown in Figure 3. Weight gain was confounded with pregnancy. In contrast, dry cows lost a smaller proportion of body weight during the dry season than lactating cows (Figure 4). June and July data are confounded by parturition and subsequent weight changes of about 50 kg per animal. Weight losses of lactating cows during the dry season are shown in Table 5, with October data representing the highest weights.



**Figure 3.** *Effect of watering regime on weight change in lactating cows, 1984–85*



**Figure 4.** *Effect of watering regime on weight change in dry cows, 1984–85.*



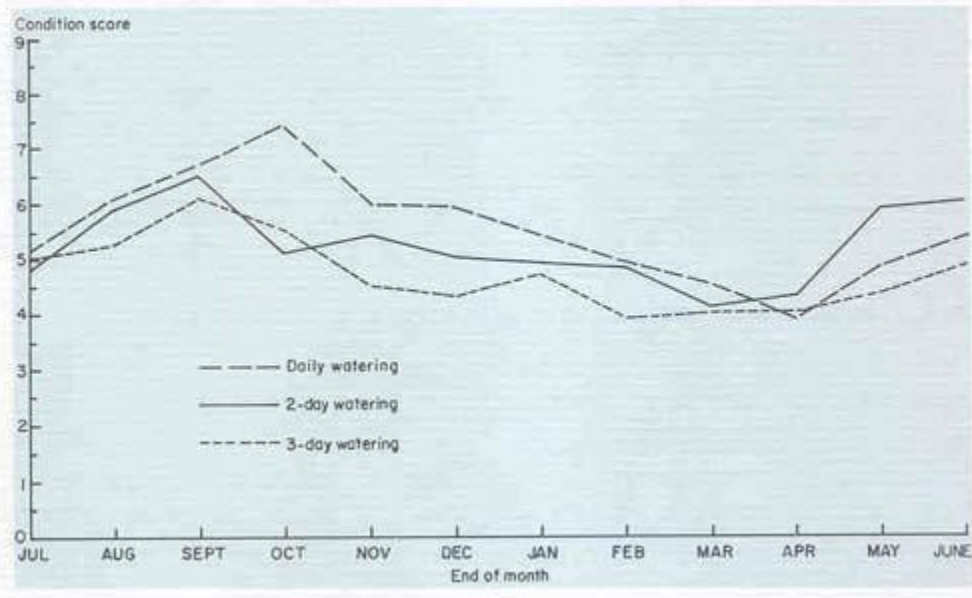
**Table 5.** *Dry-season weight loss of lactating cows, November 1983–May 1984.*

Treatment	Weight loss (kg)	Percentage of October weight
1	83.4	22.2
2	68.4	18.6
3	111.4	27.0

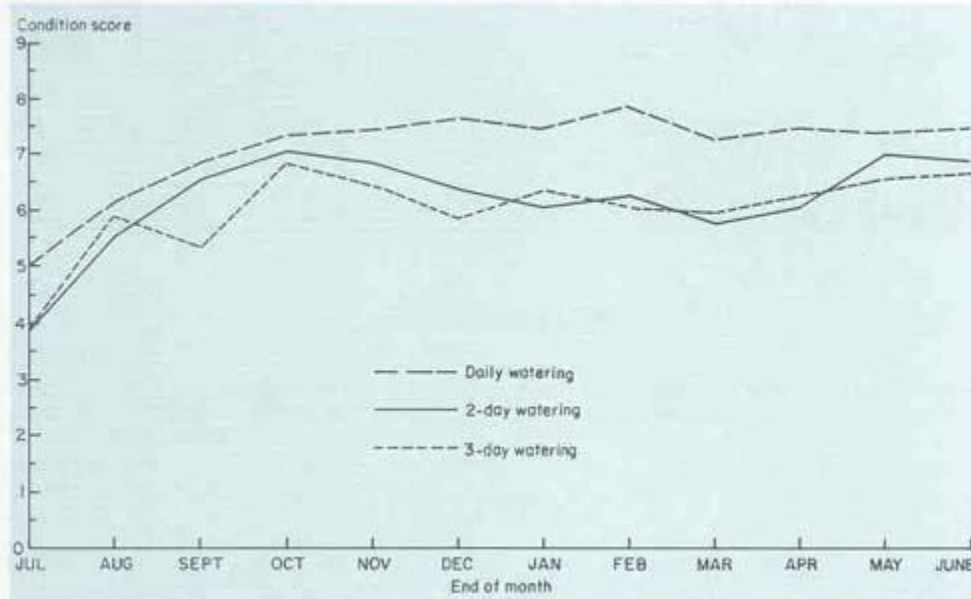
## Seasonal change in condition score

Changes in condition over a 1-year period are shown in Figures 5 and 6 for lactating and dry cows. The data have been analysed in detail by Nicholson and Sayers (1986). Condition scores for individual animals were highly significantly correlated with weight change. One condition point was equivalent to an average weight change of 18 kg and this relationship was linear ( $P < 0.001$ ). Loss of condition in the dry season was marked in lactating cows and varied according to treatment (Table 6).

**Figure 5.** *Effect of watering regime on monthly condition scores of lactating cows, 1984–85.*



**Figure 6.** *Effect of watering regime on monthly condition scores of dry cows, 1984–85.*



**Table 6.** Rate of condition loss in lactating cows over the dry season, October to April (condition score  $\pm$  S. E).

Treatment	October score	April score	Condition loss (points per month)
1	7.4 <sup>c</sup> $\pm$ 0.27	4.5 <sup>e</sup> $\pm$ 0.27	0.452 <sup>a</sup> $\pm$ 0.0039
2	5.1 <sup>d</sup> $\pm$ 0.26	4.1 <sup>e</sup> $\pm$ 0.26	0.268 <sup>b</sup> $\pm$ 0.0040
3	5.5 <sup>d</sup> $\pm$ 0.26	4.0 <sup>e</sup> $\pm$ 0.26	0.280 <sup>b</sup> $\pm$ 0.0039

Means in the same column with the same superscript are not significantly different at the 5% level.

## Water intake

There were highly significant ( $P < 0.001$ ) differences in water consumption between lactating cows and dry cows and between treatments (Table 7). The data refer to the dry season only. Wet-season water consumption was highly variable.

**Table 7.** Water consumption ( $\pm$  S. E.), September–March.

Treatment	Average consumption at drinking (litre)	Consumption (ml/kg)	Consumption (ml/kg/day)	Consumption as % of dehydrated weight
1 LC	28.7 $\pm$ 1.3	79.4 $\pm$ 2.6	79.4 $\pm$ 2.6	7.9
DC	23.3 $\pm$ 1.1	57.3 $\pm$ 3.2	57.3 $\pm$ 3.2	5.7
2 LC	54.6 $\pm$ 1.0	151.0 $\pm$ 5.7	75.5 $\pm$ 2.1	15.1
DC	42.0 $\pm$ 1.1	108.2 $\pm$ 3.3	54.1 $\pm$ 2.6	10.8
3 LC	65.3 $\pm$ 1.7	156.7 $\pm$ 6.9	52.2 $\pm$ 3.3	15.7
DC	49.9 $\pm$ 1.6	133.5 $\pm$ 4.1	44.5 $\pm$ 3.0	13.4

LC = lactating cows, DC = dry cows.

Maximum observed intake was 90 litres in a lactating cow with a dehydrated weight of 301 kg. Maximum intake expressed as a percentage of dehydrated weight was 31.4%. Water intake in steers was very similar to that in dry cows when expressed on a ml/kg or a ml/kg/day basis. Treatment 3 cows consumed up to 34% less water than cows watered daily on an intake per day basis, whereas in dry cows intake was depressed by 22%. In contrast, calves of dams in treatments 2 and 3 drank significantly more water in the first 7 months of their life than calves of dams in treatment 1.

## Milk intake

During three 10-day sub-periods, milk intake was estimated in young calves of the same age in the third month of lactation. The results (Table 8) show that treatment 3 calves consumed significantly less milk than those in the other two treatments.

**Table 8.** *Milk intake (kg/day).*

Treatment	Weighing method	Turnover method
1	4.93 <sup>a</sup> ± 0.10	5.10 <sup>a</sup> ± 0.19
2	4.82 <sup>a</sup> ± 0.09	4.78 <sup>a</sup> ± 0.12
3	4.19 <sup>b</sup> ± 0.13	4.36 <sup>b</sup> ± 0.13

Means in the same column with the same superscript are not significantly different at the 5% level.

## Feed intake

Data for faecal output and estimated feed intake of growing lactating cows and steers are given in Tables 9 and 10.

**Table 9.** *Dry-matter intake of lactating cows (crossover trial, n = 27).*

Treatment	Feed intake (g/kg <sup>0.75</sup> /day)	Mean weight of cows (kg ± S.E.)
1	68.0	320 ± 7.7
2	65.6	322 ± 8.7
3	61.8	329 ± 9.3

Linear component significant at the 1 % level.

**Table 10.** *Faecal output and estimated feed intake of steers.*

Treatment	Observed faecal output (g/kg <sup>0.75</sup> /day)	Calculated feed intake (g/kg <sup>0.75</sup> /day)	Mean weight of steers (kg ± S.E.)
1	35.9 ± 0.82	52.9 ± 2.93	248 ± 3.6
2	30.6 ± 1.61	42.3 ± 2.35	238 ± 5.7
3	31.6±0.91	46.1 ± 2.16	231 ± .1

No differences in the digestibility of feed were found between treatments as estimated by the quantity of IADF in the faeces. Faecal output was significantly higher ( $P < 0.05$ ) in treatment 1 steers than in those in the other treatments, and the estimates of DM intake suggest a 12–17% reduction in feed intake by steers in treatments 2 and 3. In the cows, DM intake was depressed by 4% in treatment 2 and by 9% in treatment 3.

## Discussion

The overall cost to animal productivity of infrequent watering was small but significant. Calf birth weights were lower in all treatments compared with control calves, and this was probably related to dam condition during late pregnancy and at parturition. When birth weights between

treatments were similar as in 1983, treatment 3 calves were 10 kg lighter at weaning than treatment 1 calves, which suggests that milk yield was lower as a result of 3-day watering. However, as total milk yield could not be measured, the lower milk intake by calves of dams in treatment 3 remains indicative only.

Weaning weights were depressed by 4, 12 and 18 kg under 1-, 2- and 3-day watering respectively against controls although there was no significant correlation between birth weight and weaning weight. Month of birth, however, affected subsequent weaning weight and in both 1984 and 1985, treatment 2 and 3 cows calved earlier than treatment 1 cows. When weaning weights were not adjusted for date of birth, there were no significant differences. To the livestock producer this is important, since 1 year after the calving season, the weight of all calves was similar even though treatment 3 calves were older. Since there was no evidence of earlier conception, the gestation period appeared to have been shortened as a result of infrequent watering. This accords with most studies where calf birth weight is significantly correlated with gestation length.

Post-weaning growth in the first year's calf crop suggested that compensatory growth was taking place at differential rates so that the differences at weaning had disappeared by 12 months of age. This was not the case in the second calf crop, in which 12-month weights were 17 kg lower in treatment 3 than in treatments 1 or 2. However, since 27-month weights were similar in all three treatments, it is doubtful whether the lower weaning weights of treatment 3 are sufficient to affect subsequent mature weights or even 2-year weights, provided the animals are put on daily or *ad libitum* watering in order to 'finish' them.

While the lower weaning weights were almost certainly linked to lower milk yield in the dry season, conception rates were unaffected. Presumably foetal demands for energy were small in comparison with lactation demands until the last trimester, at which time lactation had ceased. The lower weaning weights were not reflected in smaller skeletal size. In contrast, calf weaning weights of 50–65 kg that are commonly encountered under pastoral conditions (Nicholson, 1985b) are associated with a much smaller skeletal size, leading to delayed maturity and even the inability of the calf to express its full potential for growth.

Decreasing watering frequency significantly reduced DM intake in both cows and steers, which was reflected in weight loss, condition and, indirectly, in the weaning weight of calves. No differences in digestibility were found among treatments so that although rumen retention time was lengthened, lower rumen water content presumably counteracted any beneficial effects by reducing the efficiency of digestion. Calculated DM intake in steers expressed as  $\text{g/kg}^{0.75}$  as low due to the overestimation of the IADF% in the feed. If the animals are more selective than the grab sampling technique, the IADF% may be lower in the animals' feed than in the feed obtained by grab sampling. A lower IADF% will raise calculated feed intake but this does not affect treatment differences where the IADF% is constant among treatments.

Since 2- and 3-day watering was continued throughout the rainy season, cows in these treatments were unable to regain the condition of treatment 1 cows and so started the dry season in worse condition.

This seldom occurs under pastoral management where daily or, at worst, alternate-day watering is practised during and immediately after the rainy season when weight gain is greatest. Animals gaining weight need additional water for growth, particularly if they are also lactating,

and it appears that 3-day watering during this period is inadvisable despite the additional water in the herbage.

The fact that both Friesian x Boran crosses and Brahman cows conceived, calved and raised calves under all the treatments suggests that 3-day watering can be implemented for *B. indicus* x *B. taurus* crosses. However, the sample size was small and no definite conclusions can be drawn. In practice, *B. taurus* is introduced in order to increase productivity (e.g. milk yield) so that 3-day watering would not be applicable to such crossbreeds except perhaps in times of drought.

Under normal circumstances, 3 days is the maximum watering interval used for cattle in pastoral systems and this is less than for either smallstock (3–5 days) or camels (up to 10 days). Therefore, while cattle are not as good at conserving water as camels or smallstock, they appear to be equally good at tolerating dehydration. On numerous occasions, lactating cows were observed to drink 30% of their dehydrated weight, which is comparable to data on camels (King, 1983; Schmidt-Nielsen, 1964) and desert goats (Choshniak and Shkolnik, 1978). Previous work with African livestock has not distinguished between tolerance of dehydration and ability to conserve water.

When put on 4-day watering, no signs of behavioural stress were apparent, the cattle waiting patiently in the shade for water. The fact that 4-day watering is not practised extensively suggests that pastoralists have arrived at 3-day watering as the optimum trade-off between lower animal productivity and water- and labour-saving.

The benefits of 2- and 3-day watering are fourfold. Firstly, grazing resources further from water can be exploited. On 3-day watering, cattle can graze 21 km away from water, assuming a maximum daily walk of 14 km (42 km *in toto*). This gives access to 1385 km<sup>2</sup> on centrifugal grazing, which is nine times the area available to cattle on daily watering. This is particularly relevant to those areas in Africa where watering points are scarce.

Secondly, where water resources are limiting, a saving of 30% is considerable. With 800 000 cattle in the Borana region of southern Ethiopia, 3-day watering is estimated to save 1.5 million tonnes of water. Since labour is required to raise this water from wells, there would be insufficient labour to water cattle every day. Where machinery and fuel are required to raise water, there is a corresponding saving in fuel.

Thirdly, water intake is normally controlled by DM intake. Under 3-day watering, however, water intake dictates DM intake, resulting in fodder reserves being conserved. Fourthly, since cattle need to trek to the watering point only every third day, the potential erosion in the vicinity of water is lessened.

As a strategy for cattle production in rangeland areas, 2- and 3-day watering may be alternatives to be considered. To the Borana, the strategy is clearly appropriate and it is not as costly as might have been expected. The combined stresses of extensive walking, night enclosures and 3-day watering, all features of pastoralism, are now being investigated in the second part of the trial.

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# Management and health constraints for small-scale dairy production in Africa

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## Summary

*MILK IMPORTS TO Africa increased sixfold in the last decade and now exceed 2 million tonnes of liquid milk equivalent per year, accounting for about 30% of total consumption. They have a present value of about US\$ 800 million. Substantial increases in milk production in Africa are feasible. This paper summarises the major environmental constraints to increased production of dairy products and discusses alternative technical and organisational concepts for encouraging greater milk production.*

*Cattle in Africa are kept primarily for milk production. In pastoral societies, milk is the key product, with meat of only secondary importance. On smallholder subsistence farms, milk is universally important.*

*Three main approaches to dairy development are in use: large parastatal farms, medium-sized dairy farms in peri-urban areas and organised milk collection from subsistence farmers. In each system, output is constrained by the restricted supply of dairy stock, poor animal health, inadequate feeding, poor marketing facilities and lack of extension and adequately trained personnel.*

*The tsetse-transmitted disease, trypanosomiasis, which is found in about 40% of sub-Saharan Africa, is a major constraint to increased milk output and is largely responsible for the substantial imports of dairy products, particularly to West Africa.*

*Under traditional management, indigenous breeds of cattle are more productive than exotic breeds. However, in higher-altitude and more temperate areas of sub-Saharan Africa, crossbred cattle can out-yield indigenous stock fourfold, provided that modest improvements are made in their management and nutrition. Maintaining genetic stability in these crossbreds is, however, a major problem. Making better use of local feed resources, particularly poor-quality feeds, at the small-farm level is a promising strategy for increasing milk production. Management problems common to all dairy systems in sub-Saharan Africa include dry-season feeding, calf rearing, small-scale milk processing and reliable vaccine supplies.*

## Introduction

The slow economic growth of the countries of sub-Saharan Africa is an issue of major world concern. As agricultural output declined, food imports increased and currently meet about one-fifth of the region's cereal needs. Milk imports now exceed 2 million tonnes per year, representing about 30% of total consumption. Over the last decade, milk imports increased sixfold and their present annual value is about US\$ 800 million (von Massow, 1985).

Although Africa's overall economic progress is disappointing, important changes are occurring in the agricultural sector. The most obvious is the decline in the relative contribution of



agriculture to GDP with a rapid increase in market demand for food, particularly that of livestock origin. Consumers in all developing countries show a high propensity to spend additional income on meat and milk.

## Complementarity of crop and livestock production

Total cereal production in sub-Saharan Africa is about 42 million tonnes per annum, and is increasing by an average of only a little over 1% annually. There are, however, very large differences in agricultural growth among African countries, with some showing much larger increases than others.

Using data from *FAO Production Yearbooks*, an analysis of the trends in cereal and livestock production over the last decade in the countries of sub-Saharan Africa indicates that:

- There is a significant correlation between changes in total cereal production and in cattle numbers;
- Changes in area cultivated and cattle numbers are much more highly correlated than crop yields per unit area and cattle numbers; and
- Each extra animal in the cattle population is associated with an extra 0.25 ha of cropped land and about 200 kg extra annual grain output.

These observations, based on the African experience, are also noted elsewhere. In India's northwestern states, where large increases in wheat and rice production have occurred, one finds correspondingly large increases in milk production. In other Asian countries where rice production has increased greatly, large increases in meat and milk production have been reported. The reasons for this association of increases in food-grain and livestock production are simple and several.

1. Availability of money. On subsistence farms, cash income is extremely low because almost all produce is consumed on the farm. Consequently, there is little money available to buy fertilizer, better seed, crop protection measures or irrigation water. In the absence of a good credit mechanism, food-grain production can only be increased by finding cash to purchase these inputs. This is most readily achieved by selling more livestock products. An upward spiral can be started by increasing sales of livestock, thus generating the purchasing power needed to produce more crops. The catalyst in the system is livestock, and the initial development objective is to increase their output to produce the funds required to increase crop production.
2. Cattle provide draught power. Working bullocks are the pivotal point of farm production in many African countries, and the type and number of livestock kept by farmers are largely determined by their need for draught power for land cultivation. Typically, one pair of oxen can cultivate 2 to 4 hectares of land per year. Recent studies by ILCA in Ethiopia show a marked increase in the area cultivated by each family as bullock numbers increase. These results also show a marked change in cropping patterns with changing availability of bullock power.
3. Market demand. As the size and wealth of the population increase, the demand for more and better food escalates rapidly. Meat and milk are most people's idea of better food, and more and better cattle provide more meat and milk.

## Increasing milk production

An essential starting point to any discussion on how to increase milk production is an understanding of why African farmers keep cattle. Milk production is a key reason, but manure for fuel and fertilizer, draught power, meat production, drought insurance and capital saving are also important reasons. Attempts to increase milk production must take account of all these factors, and also of the need to use livestock as the catalyst in generating income and savings for farmers with no alternative source of cash. Proposals for the development of the cattle sector must also be extremely low-cost if they are to be adopted by Africa's small farmers.

Three main approaches to increasing milk production have been used in recent years. These are:

- Large parastatal dairies using specialised dairy cattle for intensive milk production;
- Medium-sized dairy farms in the private sector, close to major urban centres; and
- Organised milk collection from large numbers of traditional subsistence farmers, usually associated with some upgrading of cattle by artificial insemination and the provision of animal health and advisory inputs.

Large parastatal farms offer opportunities to maximise the impact of specialised management skills, to produce a high-value product close to market outlets, to minimise transport and input supply problems and to effect substantial economies of scale. The problems such farms present are associated with a reliance on purchased feed rather than pastures and crop residues, their capital intensiveness and their lack of impact on rural cash flows and productivity. The intensive nature of milk production in these units usually leads to high production costs and to the need for subsidies to ensure continuing viability. Where such farms are used as bull breeding units, AI and cooperative service centres, and as focal points for the collection and processing of more widespread milk supplies, they play a valuable role in the national dairy development strategy. Their usefulness as research or demonstration centres is, however, very limited as the production technology used is not applicable to the traditional livestock producer.

The smaller, semi-intensive specialised dairy units developed within the private sector present a similar spectrum of advantages and disadvantages. One important type of semi-intensive dairy unit is the 'flying herd' which is characteristic of many urban dairies. Typically, recently-calved cows are brought into city stables and fed and managed for maximum milk production. The resulting problems of manure disposal and feed transportation usually make the flying herd a second-best solution to providing adequate milk supplies.

Small dairy farms just outside major towns avoid many of the problems associated with the city units, but these peri-urban dairies also incur many costs that traditional mixed farmers can avoid. Most attempts to establish peri-urban specialist dairies in Africa and Asia have not been particularly successful.

The outstandingly successful experience of dairy development in South Asia is based on the so-called Anand model (Brumby, 1981). This concept began on a small scale about 30 years ago with the establishment of a small dairy-producers' cooperative in the town of Anand in west India. The success of this small cooperative quickly led to similar grass-roots movements in many other Indian states, and now more than 10 000 dairy cooperatives in Indian villages, with 2 million members, collect and process some 2.5 million litres of milk daily.

This cooperative movement is organised in three tiers: village dairy societies, unions of about 400 village dairy societies and a federation of several unions in each state. The whole system is owned by the primary milk producers who are small peasant farmers or landless owners of one or two cows. Two semi-autonomous government agencies— the National Dairy Development Board and the India Dairy Corporation—provide technical and financial assistance to the system.

This cooperative structure provides an integrated system for marketing and processing milk. The village cooperative society buys milk twice daily from its 100 to 200 members on commission at its village collection centre. The milk is immediately tested for fat content and taken by truck, without cooling, to the union dairy where it is pasteurised, cooled and either shipped to urban markets or processed into dried milk and butter. The union dairies are modern plants of relatively large capacity (100 000 to 400 000 litres per day). The entire supply for each comes from the very large number of small farmers making up the basic village societies.

Every member of the village cooperative has access to a daily artificial insemination service, to veterinary services, to concentrate feed supplements and to supplies of seed of forage crops. The success of the movement lies in a reliable and profitable outlet for all milk produced, with prompt payment based on milk quality as determined by individual fat tests, and technical assistance to increase production.

Why should this cooperative venture have succeeded so well when so many other cooperative structures have failed? The reasons for the success of the Anand model can be simply summarised. It provides a soundly conceived and financially viable package of technical services to the producer, economies of scale at critical points in the marketing system, dedicated leadership and well-trained support staff.

## **Animal health problems**

Animal health problems are closely linked to the kind of environment in which the herd is kept, the management methods used and to genetic factors related to disease resistance in the animal population. In Africa, low-cost, effective vaccines are usually available to protect against rinderpest, contagious bovine pleuropneumonia and local strains of foot-and-mouth disease. Such sporadic or regional diseases as anthrax, blackleg and haemorrhagic septicaemia can also be prevented by regular immunisations, but vaccines for these diseases are not always of high quality or uniformly available. With some vaccines, the costs may exceed the expected benefits (McCauley, 1983).

Closed management systems, in which no animals are brought into the herd from outside sources, greatly reduce the likelihood of infection by many diseases, and viral and bacterial infections that are spread by contact can be prevented. This offers an alternative to the strict use of vaccines and usually protects the herd from the severe effects of such diseases as infectious bovine rhinotracheitis, mucosal disease and, probably, salmonellosis. Such persistent problems as brucellosis and tuberculosis can be controlled by a combination of eliminating infected animals and maintaining a closed herd (Nicoletti, 1984).

But in small dairy herds in warm climates, vector-borne and parasitic diseases are the most common health problems, and the strict environmental controls necessary to eliminate these are not practicable. Many of these diseases cannot be prevented and treatment or control is expensive. Several, including trypanosomiasis and East Coast fever, are so widespread and

often beyond economically feasible methods of control that they are prime subjects of major research efforts (Gray, 1984). Others are less prevalent but even more enigmatic: these include ephemeral fever, heartwater disease, Rift Valley fever and lumpy skin disease. There are, however, three ways in which we can often live with this large group of diseases through understanding and compromise.

The first is to appreciate the too-often-ignored genetic advantage of indigenous cattle. The value of these, in tsetse-infested areas particularly, is well documented (see Brumby and Trail, 1986). The need for large increases in milk production has often led to the importation of exotic breeds, and nearly as often ended with overwhelming disease problems. The innate disease resistance of indigenous cattle, coupled with adequate diets, can offer the prospect of increased production with some assurance of permanent gains.

The second is to understand and take advantage of what can be called an 'endemic-equilibrium' state of disease. This state of tolerance between the parasite and host occurs with most of the tick-borne diseases when animals are exposed to them while young and partly resistant; they can thus acquire immunity that protects them in their usually susceptible older age. Two of the four important tick-borne diseases, anaplasmosis and babesiosis, become quite benign under this adaptive behavioural pattern. There is also some evidence that East Coast fever acts in a similar manner with indigenous cattle.

The third important epidemiological truth of practical importance is that parasitism is the normal state. This applies to many parasitic diseases. It is normal for hosts to have parasites and, if the levels of infection are not excessive and the host is not malnourished, their relationship is often more beneficial than pathogenic. This is due, again, to factors of resistance and immunity (Urquhart, 1980). Related to this is the unique fact that metazoan parasites do not replicate within their hosts. Because of their complex life cycles, associated with sexual reproduction and multiple developmental stages that require different environments, the number of metazoan parasites within a host is directly related to the level of transmission (Warren, 1981). Transmission levels can be regulated through management methods based on an understanding of parasite life cycles. This knowledge is not fully appreciated or widespread. We are, instead, conditioned to view infection as synonymous with disease and treatment with cure. These are false and unrewarding beliefs.

Disease is an important constraint on all forms of livestock production and especially for calves (Perry et al, 1984), which frequently suffer from respiratory and enteric diseases. Chronic diseases such as dermatophilosis greatly depress milk production (Oduye, 1975) and increase mortality in all age groups.

## **Calf rearing**

Allowing limited suckling of cows by their calves has a great deal to commend it as a calf-rearing technique. Supplementation of a small milk intake with leguminous forage, oilseed cake or concentrate mix increases calf growth appreciably, provided that sufficient drinking water is available, a matter that is often overlooked under smallholder conditions. This water requirement amounts to about 5.5 litres per kg of DM consumed.

Mortality in calves is also considerably decreased as increases in daily weight gain are achieved, and the subsequent rearing of weaned calves is greatly facilitated by supplementation with legume forage, oilseed cake and/or molasses/urea block.

## Research on milk production

In considering how livestock research can most usefully support the economic development of a specific region, it is important to establish what type of organisation of livestock production is likely to prevail in the next 20 to 30 years. The research problems presented by the alternative milk production systems are very different and it makes little sense to embark on a specific research programme unless a sound concept is developed of what future production patterns are likely to be. It is likely that traditional smallholder farming will continue to predominate in Africa, and that a cooperative structure linking and providing services to these small farms will emerge. Given these assumptions, it is useful to consider what type of research into increased milk production is likely to be most cost effective and how it might best be organised.

In all African countries, calving patterns show marked seasonal variations. Peak calving periods are greatly influenced by seasonal patterns of rainfall and annual feed supplies. Milk supplies and, more importantly, production costs show similar seasonal variations. Do we accept this situation, do we try to modify it by supplementary feeding and new forage crops or do we produce milk only for that part of the year when feed is plentiful, conserving the seasonal surplus as milk powder and butter for use during the season in which feed supplies are scarce?

Milk can be produced cheaply by feeding low-energy diets based on crop byproducts, supplemented with some leguminous fodder, a little oilseed cake and urea, preferably in a molasses block complex. The optimal milk yield per cow depends on its breed type, overall environmental stress and the local market value of milk. The optimal feeding level and balance of feed types in these various circumstances is largely unexplored, and little is known about the relationship between incremental levels of feeding and incremental milk yields. Data to indicate the optimal stock density per unit of arable land are inadequate, as are data about the area of fodder crop needed for each milk cow in different cropping situations and on different sizes of farm.

The much discussed question of the degree of crossbreeding desirable is now reasonably clear; animals with 50 to 75% exotic blood usually outperform more extreme crosses on a lifetime basis, but how best to maintain this level of exotic blood is unresolved. Should  $F_1$  bulls be used for each generation? Should a new breed be fashioned by intense mating of the crossbreds? Would crisscrossing be practicable? And how do we ensure a maintenance of draught capability? Genetic interactions and maternal effects also complicate the analysis of crossbreeding data, as does the small size of the herds in which field records are obtained. Within-herd comparisons are rarely possible in small herds, and using records across farms involves many additional sources of variation. Results at ILCA show that individual lactation milk records from small herds in Africa, as in Asia, have a coefficient of variation of about 30%. This high variability makes progeny testing largely impractical. It also complicates attempts to conduct experiments within the herds of small farmers.

In both Africa and Asia it is evident that some farmers are much better than others, that crossbred cows can perform better than local stock if environmental constraints are reduced, that certain forms of milk production have a much better success record than others and that sales of milk and milk products often provide the main source of farm cash income, the expansion of which is critical to increasing total farm output.

It is also evident that unattractive prices and inappropriate policies frustrate production increases in many circumstances. Important as these policy issues are, the increase in food

output so badly needed depends greatly on the development and adoption of new and simple technology. It also depends on the promotion of the organisational and entrepreneurial systems needed to put better technology into productive effect, and of building a research structure appropriate to local farming patterns. The Anand model of dairy development provides an excellent example of how effective smallholder milk production can be in promoting economic development.

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# Small ruminant production—the present situation and possible nutritional interventions for improvement

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## Summary

IN TROPICAL AFRICA, sheep and goats are raised mainly by small farmers under a low-cost system. The productivity of small ruminants can be increased through better health care and feeding, involving simple modifications to the existing farming systems rather than drastic changes. The cost-effective interventions discussed in this paper include inexpensive prophylactic measures, the maximum use of waste products from small-scale processing, household wastes and crop residues, cut-and-carry feeding and the provision of water in pens, and reserving areas of bush for dry-season grazing only.

## Introduction

Jahnke (1982) estimated that there are about 104 million sheep and 125 million goats in tropical Africa, kept predominantly within the small-farming sector. It is only in highland regions that sheep outnumber goats (Table 1). Throughout the continent there are many different breeds, ranging from small, trypanotolerant animals found in the humid zone of West Africa to long-legged, rangy animals found in most arid regions. Day length in the tropics shows little variation; females breed throughout the year and variations in birth patterns from month to month are related to the plane of nutrition at the time of conception.

**Table 1.** Ruminant livestock population by species and ecological zone in tropical Africa.

Ecological zone	Cattle	Sheep	Goats	Livestock units
		(x 10 <sup>6</sup> )		
Arid	31.5	37.1	48.3	41.7
Semi-arid	45.5	23.1	33.2	37.5
Subhumid	32.8	14.2	20.3	26.4
Humid	8.8	8.2	11.6	8.1
Highland	29.0	21.4	11.9	23.6

Mortality rates are usually high (25–40% per annum) and young stock are particularly at risk in the first 3 months post partum. Neonatal losses can be closely correlated with birth weight, which is itself a reflection of maternal nutrition during the last 2 months of gestation. The disease pattern varies from area to area and from season to season. At all times, animals that are undernourished are at high risk. Under-nutrition also lengthens kidding/lambing interval and decreases kidding/lambing percentage and growth rates, which, together with survival rate, are components of a productivity index:

Productivity index =  $KP \times 365/KI \times S \times B W$

where:  $KP$  = kidding/lambing percentage/100

$KI$  = kidding/lambing interval (days)

$S$  = survival rate to weaning, expressed as a proportion

$BW$  = body weight at weaning.

Thus any strategy to increase the productivity of small ruminants must look closely at nutrition.

## Current situation

Increases in food production in Africa are falling behind population growth and food shortages are becoming increasingly widespread. Ruminants have a distinct advantage over simple-stomached animals in being able to convert organic material unsuitable for human consumption into products of high nutritional value, while at the same time providing excellent fertilizer from undigested residues. Furthermore, in extensive farming systems, small ruminants, particularly goats, are complementary to cattle. Goats have catholic tastes and consume many more plant species than cattle. By preference, goats are browsers rather than grazers, while cattle are primarily grazers. Provided that an area is not overstocked, and in many areas of Africa that condition is unlikely to be fulfilled, goats and cattle together allow a higher carrying capacity than would be possible with either species alone.

The myth of the destructive goat should have been finally demolished by Staples et al (1942), who described the comparative effects of goats and cattle on fenced plots of semi-arid wooded grassland in central Tanzania. After 4 years of the trial, considerable modifications had been effected to the plots. Goats browsed all plants within reach, but did not browse any plant down to ground level, so that none were destroyed. Little bark damage was caused to trees, and young trees large enough to produce branches out of reach of the goats continued to grow. Thus a good ground cover was maintained at a stocking rate of approximately 1.4 LU/ha/year. In contrast, cattle at a slightly higher stocking density concentrated on the grasses and eventually produced open thicket with little ground cover. Carrying capacity was reduced and erosion accelerated. Environmental degradation was therefore more likely from cattle than from goats. It is realised, however, that when an area is overstocked with goats, as with any other livestock species, damage to vegetation will occur.

In areas of extensive farming where the soil is of low agricultural potential, animal productivity is also low. There is little competition for the land and extensive livestock systems are most appropriate to the conditions. In such areas, despite the fall in the nutritional value of maturing grasses, small ruminants are frequently better nourished than cattle because of their preference for browse (Zeeman et al, 1983; 1984). In East Africa, many browse species start to produce new growth before the onset of rains. This contributes to a rising plane of nutrition and is associated with a peak in conception rates (Walker, 1980; Reynolds, 1985). The flush of young grass that accompanies the early rains, although highly nutritious, does not result in the expected increase in production. A concurrent rise in levels of both internal and external parasites also occurs (Adeoye, 1985).

Forage availability during the dry season determines the overall carrying capacity of the land. On more fertile land the perceived needs of pastoralists and arable farmers clash. Throughout Africa population pressure is increasing; as a result former grazing areas are being used for arable farming, and the true pastoralist is restricted to a decreasing area. Although it may appear contradictory, this can be to the advantage of the pastoralist. In a symbiotic relationship, pastoralists can graze their animals on crop residues in the dry season and the settled farmers



benefit from the deposited manure. Putt et al. (1980) demonstrated that this can result in an increase in overall carrying capacity because the crop residues can support more animals than natural pasture during the critical dry period.

In areas of higher soil fertility and cropping intensity, local communities view wandering animals with disfavour and may demand that livestock be penned or tethered. Most localities, however, have areas unsuitable for cropping that can be set aside for communal grazing, but overstocking will be a hazard. Traditionally, livestock were herded by children, but with the spread of primary education, and in some places, compulsory school attendance, this source of free labour is decreasing and herders must be employed. One response to these combined pressures is stall or pen feeding, in which animals are not allowed out.

A continuum of management systems can be found between nomadic pastoralism and stall feeding. Where do small ruminants fit into these systems? In most parts of Africa, they are merely adjuncts to the farming system, although still important. It is only under special situations in moderate to high-rainfall areas, for example where tsetse flies combined with government directives exclude cattle, that small ruminants assume a dominant role. In such situations, infrastructural development is invariably poor. Farmers have difficulty marketing their animals because roads and transport to centres of population, and hence consumers, are lacking. Prices paid by itinerant buyers to farmers are low, and profits accrue to middlemen rather than to the farmers. At the other extreme, where demand for land is intense, there may be moves to exclude livestock completely.

## Scope for improvement

Small ruminants are raised under a low-cost system, and farmers are less likely to buy feedstuffs or provide veterinary care for sheep and goats than for cattle. Interventions that call for expenditure are unlikely to be adopted widely, while those that are simple adaptations of existing systems could be more acceptable.

Productivity can be increased by two major routes with a degree of interdependency. The first involves improved health care, which reduces mortality. ILCA (1985) has shown that prophylactic health measures in southwest Nigeria allowed goat numbers to increase by 118% over a 2-year period, compared with a 24% increase in control villages. However, increasing flock size is a long-term recipe for disaster if insufficient forage is available. Are more animals needed or could higher productivity be achieved through better nutrition and health care while reducing the total population? If a reduction in numbers is to accompany health and nutrition interventions, this necessitates increased offtake and hence improved marketing arrangements.

Veterinary inputs for small ruminants are unlikely to be widely available in the foreseeable future. Any health intervention must be low-cost, and preferably within the resources of the farmers themselves. Can the management system be modified, bearing in mind the constraints imposed by the farming system as a whole, to limit the incidence of disease?

The second major route is through improved feeding. The type of nutritional intervention will depend on the overall farming system employed and on environmental conditions. Certain questions must be asked whatever the farming system. What can be found on the uncultivated land? What is available from crop residues? Is the farmer aware of the nutritional value of the potential feed resources? Will using that material as animal feed fit into the existing farming system? If not, what changes will be necessary?

It can be argued that extensive systems are the most difficult to assist given the necessity of minimal-cost interventions. The major feed resource in extensive systems is uncultivated browse and grasses. Goats in particular are able to select the most nutritious plants and parts of plants, obtaining a reasonably balanced diet throughout the year. It is rare to see extensively raised goats in poor condition unless carrying capacity is exceeded. Farmers may assist by lopping branches that would otherwise be out of the reach of livestock and by providing water to animals at night. This latter intervention is particularly beneficial to lactating females since 86% of milk is water. Shortage of water inhibits milk production (Little et al, 1976).

Bush improvement may be suitable for selected areas within cattle ranches, but is generally uneconomic for small farmers raising smallstock. Communal agreement to reserve an area for dry-season feeding can however be beneficial and has been successfully adopted in some areas. One such example is in west Mzimba, Malawi (Dworela, 1980), where the reserved area was improved with *Stylosanthes guianensis* cv Cook.

A cost-effective approach is to check on mineral nutrition. Tissue and feed samples will show whether supplementation is necessary; if so, they can easily be incorporated into salt licks.

Use must be made of whatever crop residues are available. Crop residues left in the field will help to maintain soil structure through the provision of organic matter. Is it more beneficial to incorporate residues into the soil or to return manure from livestock as a byproduct of crop-residue feeding? The feeding value of a particular residue will be related to the overall feed situation. Where there is a shortage of forage, a residue of low nutritional value will assume a greater importance than when adequate feed is available. Under the latter conditions, quality rather than quantity becomes the major factor.

As human population density rises, the importance of crop-residue feeding increases relative to uncultivated forage. Livestock can have free access to arable fields after harvest in addition to whatever natural forage is available. Animals grazing maize stover always waste part of the feed by knocking it over. Contamination with soil, urine and faeces occurs, and the resultant mixture is unpalatable. A bimodal rainfall pattern limits access to first-season crop residues *in situ* because cultivation for the second crop closely follows the first harvest. Storage of first harvest maize is difficult in the absence of drying facilities, so it is often picked green. The remaining stems and leaves can be fed to animals. Farmers can carry forage to the animals each day during harvest, to feed in the pen at night. Any wastes can be composted to fertilize vegetable gardens or can be returned to the fields. Access to fields after the second harvest is less restricted and labour is more readily available for collection and transportation of residues to animal pens. In many areas, maintenance of soil fertility depends on the inclusion of fallow periods in the farming system. Regrowth during these periods can be made available to animals.

Alley farming—growing rows of leguminous trees such as *Leucaena leucocephala* and *Gliricidia sepium* with food crops between the rows—provides mulch and browse to the advantage of both crops (Table 2; Attah-Krah et al, 1986) and livestock (Table 3; Reynolds and Adeoye, 1985). The leguminous trees provide high-quality, cut-and-carry feed for confined animals. The trees are managed for maximum forage availability in the dry season. In addition, mulch nitrogen helps to maintain soil fertility (Kang et al, 1985) and reduces the need for a fallow period, so that a larger proportion of land can remain under cultivation. The resultant crop residues are important feed resources during the dry season.

**Table 2.** *The effect of alley farming on the yield of maize cobs in southern Nigeria.*

	Maize yield (t/ha)				
	1983	1984		1985	
	1 <sup>st</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season
Continuous cropping (control)	2.19	2.55	1.16	2.49	1.09
Continuous alley Cropping	2.54 (1.16)	3.75 (1.47)	1.45 (1.25)	2.83 (1.14)	2.00 (1.83)
Alley grazing/cropping	–	–	–	3.88 (1.56)	2.40 (2.20)
Alley cropping/grazing	2.56 (1.16)	3.43 (1.35)	1.27 (1.09)	–	–

Values in parentheses indicate yields as proportions of control yields.

**Table 3.** *The effects of supplementary leucaena and gliricidia, with ad libitum Panicum maximum, on the productivity of West African Dwarf sheep (means  $\pm$  S.E.).*

Browse (g/day):	0	400	800
Parturition interval (days)	262 +13.5	226 + 8.4	241 + 8.9
Litter size	1.26 +0.087	1.19 + 0.082	1.17 + 0.078
Survival to 90 days	0.65	0.65	0.82
Birth weight (kg)	1.80 +0.069	1.52 + 0.073	1.72 + 0.067
Daily liveweight gain to 90 days (g)	64.4 + 2.98	73.4 + 4.98	83.8 + 3.69
Productivity index <sup>1</sup>	8.67	10.15	13.46

<sup>1</sup>Productivity index = kg lamb weaned/dam/year.

Household and small-scale food processing wastes such as maize bran and cassava peels may also be available. Maximum use must be made of these since they are energy sources and complement the high-protein browse. Less wastage of feed occurs in cut-and-carry systems, but the labour requirement is high.

In the Oume province of the Republic of Benin, where animals are confined and raised under a cut-and-carry system, forage is deliberately spread on the floor so that much of it becomes unpalatable. Food residues, mixed with urine and faeces, are composted *in situ* and the resultant fertilizer is highly valued. The animals are kept to provide fertilizer, with meat as the byproduct of the system (Attah-Krah, personal communication).

Where there is only a limited amount of supplements available, preferential feeding to animals in late pregnancy and lactation is advisable. This will ensure that animals under the greatest

nutritional stress will benefit. In intensive systems, the provision of extra rations prior to mating (steaming-up) has been demonstrated to increase litter size, particularly when breeding females are in poor to moderate body condition initially. Steaming-up would be difficult to implement in extensive systems with year-round breeding, but it could be used where animals are confined.

Within birth type classes there is a close inverse relationship between birth weight and mortality rate. Single offspring are heavier at birth than twins, which in turn are heavier than triplets. Neonatal deaths among offspring from multiple births are higher than among singles. Under-nutrition of the dam during the final 2 months of gestation, when foetal growth is greatest, will reduce birth weight. It is possible to select for twin-bearing females in order to increase the overall kidding percentage of the flock, but unless adequate nutrition is provided this may result in a higher mortality rate. Improvement of the genetic base must therefore be accompanied by good nutrition otherwise the additional potential, gained at such cost during selection over a number of years, cannot be realised.

Selection for increased growth rates to weaning is, in part at least, selection for higher milk production from the dam. Milk yield will depend on body condition, nutrient intake and number of offspring being suckled, as well as on genetic potential. When the CP level in grasses is low and lignin levels are high, as happens after flowering, digestibility is low. At this stage the provision of additional nitrogen, whether from browse or from urea, will increase rumen microbial growth rates and hence digestibility. This in turn will be matched by a higher feed intake because of faster passage of food through the gastrointestinal tract. Thus the nutrient intake of lactating females on poor-quality forage can be greatly increased by providing browse.

Milk production from small ruminants kept for meat has received little attention in Africa, and it may be useful to extrapolate from cattle data. Differences in response to supplementary feeding during lactation have been noticed between beef and dairy breeds. Incremental increases in the feed intake of dairy cows have most effect on total lactation milk production during the early lactation period, their effect declining thereafter (Broster et al, 1969). Hart et al (1975), in a matched-pair trial with beef and dairy cows, showed that beef cows gained weight but produced little milk, while dairy cows on the same level of feeding lost weight but had a high milk yield. Supplementary feeding at any stage of lactation to African small ruminants and to zebu cows produces a response comparable to that observed in temperate beef cattle. Genetic selection for high milk production has increased the importance of early lactation feeding, but in meat animals the timing of supplementation during lactation is less critical. Nevertheless, milk production is important, ensuring as it does a high pre-weaning growth rate. Zebu cows are sometimes expected to provide milk for humans as well as for the calf, often to the detriment of calf growth. Lambs and kids are less likely to be affected, since human consumption of sheep and goat milk is less widespread.

## Conclusion

Small ruminant production by small farmers is at present a low-cost enterprise. Development agencies must take this fundamental point into account and look first for modifications of the existing farming systems before proposing drastic changes. Low-cost interventions might include provision of water in pens, maximum use of residues from small-scale food processing, household wastes and crop residues, and the reservation of areas of bush for dry-season use. The use of leguminous trees for browse should be considered.

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# Research with a farming systems perspective at ILCA

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## Summary

*ILCA HAS USED a systems approach to research since the Centre was established. This strategy was adopted because of the original belief that technical answers were available for many of the problems limiting Africa's livestock development, but that not enough was known about the functioning of the production systems and how to introduce change in them. A better understanding of the systems and adaptive research were necessary to identify relevant improvements.*

*The objectives of ILCA's systems research are to diagnose constraints to increased animal production, to develop prototype technologies under farm conditions, to develop research methodologies, to monitor technology adoption and to help develop the systems research capacities of national institutions in Africa.*

*This paper summarises ILCA's strategy in and experiences with systems research. It discusses the findings and progress to date of the Centre's programmes on smallholder farming in the Ethiopian highlands and on smallholder farming and agropastoralism in the humid and subhumid zones of Nigeria. Experiences in the pastoral systems of eastern Africa (Ethiopia and Kenya) and western Africa (Mali and Niger) are also discussed.*

*Field experiences have shown that little modern technology was available that had substantial advantages over traditional methods, given the economic and ecological conditions facing producers. As a result, ILCA has recently placed more emphasis on component research on such topics as forage legume agronomy and animal nutrition in order to generate new technology.*

*ILCA will continue with systems research through field programmes undertaking applied and adaptive research, supported by component research by HQ units. The Centre will also continue to give high priority to training national programmes in techniques appropriate to livestock production research in sub-Saharan Africa.*

## Introduction

The International Livestock Centre for Africa (ILCA) was established in 1974 to:

- Serve as a multidisciplinary institution for research to improve livestock production systems in sub-Saharan Africa;
- Provide training to increase regional competence in the systems approach to livestock research and development; and
- Act as a multidisciplinary documentation centre.

Livestock improvement at ILCA is only a means to an end: the Centre's overall objective is to increase food production in sub-Saharan Africa by maximising the contribution of livestock and through better integration of crop and livestock production.

The Centre has used a systems approach to research since it was established. This strategy originated from ILCA's Foundation Report, which stated that 'technical answers are available to many of the specific problems facing livestock development in Africa. The major constraint lies rather in the difficulty of introducing change into existing socio-economic systems, combined with inexperience in adapting technologies to suit local conditions' (Tribe et al, 1973). The approach was reinforced by the experiences in development projects, which showed that Western technology and the results of classical on-station research, whether in Africa or elsewhere, could not be transferred directly to African traditional systems. A better understanding of these systems and adaptive research were necessary to identify relevant improvements.

ILCA's research programme is characterised by decentralised field research teams in the major ecological zones of the subcontinent, supported and complemented by central component research units (Table 1). Networks provide a bridging mechanism between ILCA and national research programmes. Networks have been established on trypanotolerance, animal nutrition, forage legume agronomy, small ruminants and camels, livestock policy, animal productivity and information.

**Table 1.** *ILCA's research programmes.*

Component research units	Field programmes (location)
Headquarters (HQ)	East Africa
Animal Nutrition	Highlands (HQ)
Reproductive Physiology	Ethiopian Rangelands (HQ)
Small Ruminants and Camel	Kenya Rangelands (Nairobi)
Forage Legume Agronomy	
Pastoral Ecology	West Africa
Livestock Economics	Humid Zone (Ibadan, Nigeria)
Nairobi	Subhumid Zone (Kaduna, Nigeria)
Livestock Productivity	Arid and Semi-arid Zones
and Trypanotolerance	(Bamako, Mali; and Niamey, Niger)

## Objectives and strategy

The objectives of ILCA's systems research are to:

- Diagnose constraints to increased animal production;
- Develop prototype technologies under farm conditions;
- Develop research methodologies;
- Monitor technology adoption; and
- Help develop the systems research capacities of national institutions.



In pursuing these objectives, ILCA has:

- Operated field teams in sub-Saharan Africa which test the systems approach and develop and evaluate specific techniques;
- Provided direct support to national research institutes in systems research;
- Developed and tested methods for rapid appraisal of pastoral and smallholder systems and of the effects of interventions;
- Begun to prepare manuals on livestock systems research for national programmes; and
- Participated in training courses in farming systems research by providing a 'livestock slot' in training courses organised by other organisations, and by organising courses on livestock systems research.

## **Approach**

### **The historical context of ILCA's research**

The assumption that solutions were known to many problems in African livestock production led to ILCA placing emphasis on zonal field programmes, as opposed to research at headquarters. Because of large differences in production systems among the ecological zones, it was believed that it would be difficult to transfer results between zones, making the decentralised approach necessary.

The field teams shared common assumptions about the base of knowledge at the outset of research, and about research methods. Among those assumptions was the need for emphasis on multidisciplinary systems research rather than component research. Much of ILCA's original work was published under the rubric of 'Systems Studies'.

There was also emphasis on on-farm, as opposed to on-station, research. This was due partly to the assumption that technical answers were available, and partly to the assumption that, where there were no technical answers, on-farm research was necessary to identify priorities for on-station research.

There was also an emphasis on the development of research methodologies. It was argued that livestock research was different from crop research. On-farm research with livestock has been said to be more complicated than with crops, because of the smaller number of animals per farm, multiple products, the lower degree of control due to the mobility of the animals, the daily rather than seasonal inputs required for animals, the greater influence of individual management factors, the extended time periods needed for experiments and the difficulties in achieving statistical significance with small samples (Bernsten, 1982).

### **Principal types of animal production systems**

The principal types of livestock production systems in sub-Saharan Africa are pastoral, agropastoral, smallholder and ranching.

Pastoral systems involve extensive grazing, little agriculture and usually some degree of nomadism. Smallholder systems involve restricted grazing, exploit crop–livestock interactions (such as feeding crop residues to the animals) and incorporate livestock as a subsidiary

enterprise to cropping. Agropastoral systems are a transition between the pastoral and smallholder systems. Ranching is of little importance in most of sub-Saharan Africa.

Pastoral systems are more difficult to study than are smallholder systems due to:

- The greater mobility of the animals, the larger area exploited, communal land tenure and, in some cases, the lack of a fixed land base;
- The difficulty of identification of and access to production units, which are often widely separated;
- The longer cycles of drought and post-drought recovery;
- The lack of well developed databases for pastoral systems, including relevant on-station research; and
- Higher research costs per sample unit in low population density areas typical of pastoral systems.

Smallholder farming systems have higher population densities, higher production potentials and more diverse technological alternatives for change than pastoral systems. One problem with attempts to introduce new technologies is that there are many complementarities between crop and livestock enterprises. Therefore, evaluation of a new livestock technology should be done on a whole-farm basis.

## Stages in ILCA's systems research

*The diagnostic stage:* Typically, this has included a baseline survey taking 3 to 6 months and longer term surveys (3 to 4 years) to describe existing systems. Researchers use farm-management and livestock productivity surveys and household studies. Recently, aerial surveys and satellite imagery have been used effectively in support of these activities. This stage defines the ecological, technical, economic and social context in which improvements are to be made, and identifies constraints to those improvements. It is not analogous to the surveys that define recommendation domains (Byerlee et al, 1980) because those domains were (very broadly) defined in the choice of ecological zone.

*The design stage:* This stage involves design of potential improvements. Their likely impact on the environment and on welfare is sometimes assessed through simulation and cost-benefit models. Research on the different components of the systems is then carried out at sites representative of the target area for improvement, taking into account other features of the system.

*The testing stage:* The potential improvements are tested in producer-managed trials. The methods for organising on-farm trials with livestock are not yet well defined, and various alternatives have been explored. The approach has varied according to whether smallholders or pastoralists have been the target population.

*The extension stage:* Technologies that are successful in the testing stage are made available to national extension services, whose participation is sought in all stages of FSR. Adoption is closely monitored to enable redesign and retesting if needed.

## Summary of ILCA's experiences

### Smallholder farming in the Ethiopian highlands

The objective of the Highlands Programme is to improve smallholder systems by increasing the efficiency of their livestock components. Particular emphasis is placed on the interactions between livestock and crop enterprises. Research is carried out in two highland areas, representative of the medium (Debre Zeit, 1800 m a.s.l.) and high altitude (Debre Berhan, 2800 m a.s.l.) zones of Ethiopia. The two are sufficiently different to require separate efforts.

The Programme first conducted rapid baseline studies at each location, to identify the major constraints limiting smallholder productivity. These are:

- Low soil fertility and high rates of erosion on slopes;
- Shortages of wood, resulting in manure being used as fuel rather than as fertilizer;
- Dry-season feed shortages, causing production losses in livestock;
- Variation in work oxen ownership, causing differences in areas cultivated, cropping patterns and income;
- Poor drainage of fertile bottom lands, limiting production of grain and crop byproducts;
- High mortality of young stock due to liver fluke and other parasitic diseases; and
- Marketing constraints for livestock products.

Station research has focused on soil fertility, forage production, draught animal utilisation and vertisol management.

The urgent need to increase productivity compelled the Programme to reduce the station-testing period for some technologies and to use farmers as test agents as early as possible. For example, the single-ox plough was offered to test farmers after less than 6 months of on-station testing.

It was recognised that local agriculture should be continuously monitored. Therefore, ILCA started ongoing studies with control farmers in the area surrounding each station at the same time as the on-station research was being started. This provided time-series data on the dynamics of the agricultural systems and baseline information against which the impact of innovations could be evaluated.

At Debre Zeit, on-farm testing began soon after the establishment of the research station, with 18 farmers trying a dairy-husbandry package. The 18 farmers adopted the package at their own risk and expense and decided whether or not to accept ILCA's recommendations. Extension inputs were provided by ILCA for the first two-and-a-half years and then gradually reduced to correspond to conditions that would normally apply in a development setting (Gryseels and Anderson, 1983). The performance of the test farmers was monitored and compared with that of farmers who did not adopt the package. The package substantially increased the farmers' cash incomes, but other constraints to adoption became apparent, including poor marketing facilities, high calf mortality, seasonal labour shortages and problems with breeding management and forage crop cultivation. These are now being addressed in component research.

The Programme monitors the impact of innovations on test farms and the voluntary spread of these innovations through the target farming communities. The Programme's strategy has been

to have as many test farmers as practicable at an early stage in on-farm testing so as to be able to quantify the whole-farm impacts of innovations. The results of the monitoring indicate any constraints to the adoption of innovations. Different groups of test farmers are used for different innovations, partly because they represent different recommendation domains and partly because of the difficulties in interpreting results if more than one innovation is tested by one farmer at any time. On-farm testing is in progress for the use of single oxen for cultivation instead of the conventional pair, the use of crossbred cows as draught animals, vertisol management through the use of broadbeds and furrows made using oxen-drawn implements, and water harvesting in small ponds and dams constructed using oxen.

The Programme collaborates closely with the Ethiopian Ministry of Agriculture in on-farm testing to facilitate the introduction of new technologies in both the study areas and other similar ones. On-farm trials have identified additional constraints to production which, according to their importance and 'researchability', are now being examined in applied on-station research. In some cases this has necessitated more sophisticated research than was originally anticipated.

## Smallholder farming in the humid zone

The Humid Zone Programme is based at Ibadan, Nigeria. Its client production system is the mixed farming of the forest, in which small ruminant production is important. Major characteristics of the zone are tree crops, a high incidence of trypanosomiasis, mixed cropping and crop rotations incorporating fallows to restore soil fertility.

The Programme's initial diagnostic work, which began in 1979/80, focused on studies of village flocks, and indicated that PPR (*peste des petits ruminants*) was the major constraint to increased sheep and goat productivity. Vaccination of susceptible animals reduced adult goat mortality by an average of 50%. Further studies showed that, if PPR was controlled, flock sizes could double in 27 months, indicating that feed supplies would have to be increased to feed the larger number of animals.

The Programme then turned its attention to providing more feed through alley farming with leguminous trees, a system developed by the International Institute of Tropical Agriculture (IITA). The basic alley farming system was tested in a limited series of on-farm trials to identify necessary modifications to the system, since the IITA trials had not included a livestock component. On-station research was started in 1982 to modify the system to meet the needs of the farmers.

Current and future work in the humid zone has the following stages:

- Health and productivity monitoring of flocks;
- PPR campaign design and evaluation;
- Alley-farming trials on station, especially to evaluate different legume-tree species;
- Monitoring of alley farms, especially and tenure problems;
- Economic analysis of alley farming; and
- Alley farming networks in similar parts of West Africa to investigate the system's potential over wider areas.

After 6 years of research, the Programme initiated and assisted in the implementation of a small-ruminant development project in cooperation with the National Livestock Projects Unit (NLPU) of the Federal Livestock Department of Nigeria. This project involved 60 farmers in

1985, and is based on a development programme that includes the results of ILCA's research on animal health and feeding.

## **Agropastoralism in the subhumid zone**

ILCA's Subhumid Zone Programme is based in Kaduna, Nigeria. The zone receives 1000–1500 mm average annual rainfall and has relatively good potential for crop and livestock production. Tsetse pressure has been high, but is decreasing as human population density, and hence cultivation intensity, increases. This has allowed higher livestock populations in the zone (Bourn, 1983).

The Programme's research began in 1979 with the assumption that nutrition was the primary constraint to increased livestock production and, as a corollary, that purchased feedstuffs would be too expensive or unavailable, so that increased forage production would have to be the main solution to the nutrition problem. Various interventions have been evaluated, including fodder banks with *Stylosanthes* species and intercropping food crops with forage legumes.

An animal nutrition research programme was established in close collaboration with the National Animal Production Research Institute (NAPRI) of Nigeria. First, on-station trials were conducted to determine animal feed requirements. Subsequently, researcher-managed on-farm trials were conducted to determine the best crops for meeting the feed requirements. Farmer-managed trials were then done with the collaboration of the NLPU in a smallholder dairy scheme.

The case of animal health illustrates how the work of other disciplines was related to the central hypothesis—inadequate nutrition. One of the proposed technologies for relieving nutritional stress is the use of fodder banks, in which herders grow legume forage crops for 4 to 5 years on the same site. It was reasoned that this system might be improved by including more productive animals, such as crossbred dairy cattle. Because those animals are more susceptible to disease than are the local breeds, research was begun to investigate disease problems. This involved incorporating crossbreds into herds and comparing their performance with that of local breeds.

Much of the Programme's current work is in evaluating the economics of the proposed animal nutrition interventions. Computer simulations are used to test the sensitivity of the profitability of fodder banks or intercropping to changes in meat and milk prices, herd structures and investment costs. This provides feedback into further station research and into on-farm trials with the proposed technologies.

## **Systems research in pastoral areas of eastern Africa**

By the 1970s it was widely realised that development projects aimed at pastoral systems in much of sub-Saharan Africa were not achieving their objectives. It was assumed that this was largely due to poor design, ensuing from inadequate understanding of pastoral systems. It was expected that increased knowledge of pastoral systems would identify constraints and allow effective interventions to be de-designed. ILCA therefore started a series of interdisciplinary baseline studies in Ethiopia and Kenya.

### **Kenya**

The main objective of the Kenya Rangelands Programme was to make an in-depth study of one specific traditional livestock system, which would consider the components of the system and the internal links within the system. The focus of the work was to make a detailed examination of the causal relationships between the various components or parameters of the system leading to the establishment of a methodology for systems studies, rather than to describe the system and determine constraints.

A wealth-stratified random sample of households in a relatively small area (1600 km<sup>2</sup>) was chosen for the descriptive phase. While the household was the sampling unit, considerable attention was paid to intra-household and inter-household parameters affecting production. The intra-household focus yielded information on the division of resources and responsibilities within the family. The inter-household focus yielded understanding of control and maintenance of water and grazing, joint arrangements in livestock care etc. Two years' data were collected on such economic aspects as changes in livestock holdings, income, expenditure and labour and such technical parameters as primary and secondary production, milk offtake and seasonal weight changes in livestock. Aerial surveys were also used to estimate domestic and wildlife biomass and their movements. The Kenyan Ministry of Livestock Development cooperated in the veterinary studies of the descriptive phase.

## Ethiopia

The Ethiopian Rangelands Programme (ERP) was set up in conjunction with the government's Rangeland Development Project (RDP). The ERP's objective was to investigate technical options for increasing the productivity of range systems in Ethiopia and associated African areas. The RDP had previously identified poor distribution of water points as a major constraint and had established a number of rainfed ponds in the preceding 4 years. RDP had also initiated measures for disease control, vaccination and cooperative cattle fattening systems. ILCA's research thrust was to acquire more data on specific production constraints and on the impact of the RDP's interventions.

The Ethiopian Rangelands Programme's descriptive phase differed significantly from that of the Kenyan Programme in two ways. It covered a larger area (16 000 km<sup>2</sup>) and the research was designed and executed in closer collaboration with a government agency. In addition, satellite imagery was used to define ecological subunits in the area, in which aerial surveys were carried out. Research focused on communities which used the same dry-season water points within each ecological subunit. Later, household budget and livestock productivity studies were carried out on each household and/or herd.

The Programme focused its diagnostic studies in 11 widely distributed parts of the study area. The aspects studied included milk supply and calf growth, rangeland utilisation, management strategies, household budgets and marketing. Particular attention has been paid to the effects of watering frequency on animal productivity, to the effect of low weaning weights on herd productivity, to the possibilities of improving incipient agriculture and to interplanting cereals with forage legumes. Bush control and use of animal traction for pond maintenance, and the possibilities of increasing milk offtake for human consumption without reducing calf growth are also being studied.



## **The arid and semi-arid zones of West Africa**

The arid and semi-arid zones have several characteristics that differentiate them from other mandate areas. They differ from the adjacent humid and subhumid zones in having a shorter growing season, lower human population densities, more ruminant stock per caput, lower soil fertility and less diverse cropping patterns. As a result, dry-matter yields are low, dry-season nutritional stress is severe, crop and animal production are risky and pastoralism is the dominant mode of land use. The zones differ from the eastern African pastoral systems because of the greater importance of cropping, transhumance and trade.

Research in these zones began with diagnostic studies of herd and farm management to determine constraints. Like pastoral systems research in eastern Africa, much of the work was based on the assumption that insufficient information was available about pastoral systems and the cropping systems associated with them. Various types of studies were undertaken including on-station research on draught animal nutrition, household budget studies, pasture studies, herd and flock management research and aerial surveys. Systems in the zone were broadly described as cultivation systems based on annual crop production by settled farmers, and transhumant systems based on pastoral production by semi-sedentary herders, with varying degrees of annual crop production.

The diagnostic phase showed that the principal constraints to animal production were poor nutrition, especially in the dry season, and poor herd and pasture management. Poor nutrition reduced the work capacity of draught animals at the beginning of the cultivation season, and affected meat and milk animals by increasing calf mortality, extending calving intervals and reducing weaning weights. Herd and pasture management were shown to affect the quantity of forage available and, ultimately, animal production.

Separate solutions to the nutrition problem were developed for the cultivation and transhumant systems. For the former, crops were identified that fit into the cultivation system, such as cowpea and forage legumes. For the transhumant and semi-sedentary systems, in which large stock (cattle and camels) are an important component, pasture management techniques that can increase primary productivity were identified. Flock-management techniques that increase secondary productivity without changes in primary productivity were also identified.

Studies on draught animal feeding at Niono in central Mali showed that better fed animals could plough larger areas earlier in the season. The nutritional improvement could be achieved by feeding legume hays, especially cowpea, and cottonseed cake, both of which are produced locally. Studies of flock management showed that changes in veterinary and breeding practices could increase small-ruminant production.

## **The role of modelling**

Quantitative models are used principally for economic evaluation of technologies. The models have been used in two ways: to assess the profitability of interventions and to assess constraints in a system, thus indicating technical solutions.

The best example of the first use is a simulation model of supplementary feeding to a dairy cattle herd. This model, first developed at Texas A&M University, and modified by ILCA using data from Botswana, is being adapted for use in Mali and Nigeria. Other examples are component evaluation of fodder banks in the Sub-humid Zone Programme at Kaduna and of

alley farming in the Humid Zone Programme at Ibadan. This work uses station and farm data but is less comprehensive than herd simulation in that it evaluates only components, not the whole system. It is also less demanding in programming capacity and is better suited as a training instrument.

Examples of the second type of model include linear programming work in the Highlands Programme, where the database from on-station trials and from farmers' fields at two sites is well established. This work fits into the category of whole-farm evaluation as a guide to component research. Another example is the use of primary production simulations to examine the aggregate pastoral production potential of large areas. This work is done for much larger physical areas than the models mentioned above and is primarily concerned with definition of production possibilities for given ecologies, rather than technology evaluation. This is being done in Botswana and in Mali. The Ethiopian Rangelands Programme has also used simple simulation models to study the impact of calf growth on herd productivity.

Models are being developed to simulate aspects of pastoral systems and to test farming components in areas with higher population densities where annual cropping dominates. Some mix of these types of model may soon be applied to data from the Kenya Rangelands Programme, where the descriptive phase of research has been completed, and where a substantial amount of field data exists.

## **Cost-benefit studies**

Some cost-benefit analysis of ILCA's interventions has been done. Work in the Ethiopian highlands has shown smallholder dairy enterprises based on crossbred cows to be highly profitable (Gryseels and Anderson, 1983). Partial budgeting has shown a small ruminant health package and supplementary feeding with leucaena foliage to be profitable under some circumstances in the humid zone (Sumberg et al, 1985). Partial budgeting has also shown fodder banks to be profitable in the subhumid zone (von Kaufmann, 1984). Similar exercises in the Ethiopian rangelands have shown promising results for calf supplementation. Some cost-benefit work has been done by ILCA in Mali and in Malawi on cattle fattening programmes. While this latter example is not directly linked to an ILCA field programme, it is an example of this technique being used in collaboration with a national programme.

## **Evaluation**

### **Fulfillment of objectives**

*To diagnose constraints to animal production:* This objective has been fulfilled in each of the major production systems.

The initial baseline surveys identified the general factors listed below as the principal constraints on animal production in the various zones:

Pastoral systems: Low dry-season feed quality, inadequate water supplies, and competition between people and calves for limited milk supplies.

Humid and subhumid zones: Animal diseases, poor feed quality and low soil fertility.



Ethiopian highlands: Availability of animal draught power; high mortality of young stock; liver fluke in sheep; inefficient water conservation and utilisation; inadequate supplies of protein supplements.

Although these constraints are of a general nature, the baseline surveys enabled them to be quantified and ranked in order of importance in each system, and allowed relevant research strategies to be defined. A crucial product of this process is the specification of desired technology characteristics.

*To develop prototype technologies under farm conditions:* No notable successes in development of new technology have been achieved in pastoral systems, but this has been due primarily to the emphasis in these systems on description rather than on development of interventions. In the smallholder systems, promising beginnings have been made in single-ox traction, fodder banks and alley farming with small ruminants, but these technologies have yet to be widely adopted.

*To develop research methodologies:* ILCA has developed techniques, or adapted them from other areas, for surveys, field research, on-farm research and monitoring with a reasonable degree of success. Techniques specific to pastoral systems, such as wide-scale aerial surveys, have proved useful. The Centre has been less successful with analytic techniques in FSR and with on-farm experimentation.

*To monitor technology adoption:* Substantial progress has been made in monitoring the adoption of ILCA-developed technologies in the Ethiopian highlands, and in the Humid and Subhumid Zones Programmes. Only minor interventions have been developed for pastoral systems, precluding monitoring of adoption. However, the pastoral systems programmes have had some success in monitoring ecological changes.

*To help build the capacities of national institutions:* In systems research ILCA has been successful in this objective, as shown by its close collaboration with national programmes in Nigeria, Mali, Kenya and Ethiopia. Institution building has been successful with smallholder systems, but less so with pastoral systems, because of the practical difficulties noted earlier in working with the latter and because of the relative weakness of national programmes in pastoral systems research. ILCA has also had effective collaboration in FSR-related work with national programmes in some countries in which it does not have resident scientists (Malawi, Zimbabwe and Rwanda).

## Summary and outlook

Research at ILCA has broadly followed a multidisciplinary systems approach. When ILCA was founded it was generally believed that sufficient 'modern' technology was available to improve traditional livestock systems, but that not enough was known about the socio-economic environment in which livestock producers operated. ILCA therefore established field teams in the various ecological zones of sub-Saharan Africa with a heavy socio-economic emphasis, in order to study the major animal production systems and the interactions among their socio-economic and environmental components. Emphasis was given initially to detailed baseline studies and the transfer of existing technologies.

ILCA's experiences have shown that little 'modern' technology was available that gave substantial advantages over traditional methods, given the economic and ecological conditions

facing producers. As a result, the Centre has recently given more emphasis to component research, such as forage legume agronomy and animal nutrition, to generate new technology. The prime concern in this work is how changes in plant and animal nutrition and physiology influence the productivity of the livestock component and of the farming system as a whole.

ILCA continues to give a high priority to its task of strengthening national institutes. In that role, it sees its comparative advantage as being in such areas as germplasm collection, data analysis, documentation and information, survey techniques, training and network development. The Centre sees its future role in systems research as continuing to have its own field teams in order to undertake original research, to test technology components developed by headquarters units and to organise training for national programmes in techniques appropriate to livestock production research in sub-Saharan Africa.

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## List of abbreviations

AI	artificial insemination
a.s.l.	above sea level
CP	crude protein
DM	dry matter
ERP	Ethiopian Rangelands Programme
FSR	farming systems research
ha	hectare
IADF	indigestible acid detergent fibre
IITA	International Institute of Tropical Agriculture, Nigeria
l	litre
LU	livestock unit (250 kg LW)
ml	millilitre
NAPRI	National Animal Production Research Institute, Nigeria
NLPU	National Livestock Project Unit, Nigeria
PPR	<i>peste des petits ruminants</i>
RDP	Rangeland Development Project, Ethiopia